



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/GB88/00950 (22) International Filing Date: 7 November 1988 (07.11.88) (31) Priority Application Number: 8726137 (32) Priority Date: 7 November 1987 (07.11.87) (33) Priority Country: GB (71) Applicant (for all designated States except US): J.H. FENNER & CO, LTD. [GB/GB]; Marfleet, Hull, North Humberside HU9 5RA (GB). (72) Inventor; and (75) Inventor/Applicant (for US only) : BROOKES, Christopher, Anthony [GB/GB]; 43 Beverley Road, South Cave, Brough, North Humberside HU15 2AU (GB). (74) Agent: W.P. THOMPSON & CO.; South Church Side, Hull, North Humberside HU1 1RR (GB).		(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US. Published <i>With international search report.</i>
(54) Title: A PROCESS FOR MODIFYING THE SURFACE OF HARD ENGINEERING CERAMIC MATERIALS		
(57) Abstract In a process for modifying the surface of a hard engineering ceramic material, a point or line load is applied to the surface of the hard engineering ceramic material by a second material such as to cause plastic deformation of the hard engineering ceramic material. To this end, the said second material is repeatedly traversed across the surface of the hard engineering ceramic material. The process is advantageously applied to a first engineering component fabricated from the hard engineering ceramic material and a second engineering component fabricated from the second material. The second material may also be a hard engineering ceramic material, and may be of the same hardness as the hard engineering ceramic material to be treated. The first and second components are used in a tribological application and between them define a point or line contact such that in use the second engineering component defines the surface of the first engineering component. The first engineering component may comprise a piston ring and the second engineering component may comprise a piston cylinder, or vice-versa.		

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DESCRIPTIONA PROCESS FOR MODIFYING THE SURFACE
OF HARD ENGINEERING CERAMIC MATERIALS

The present invention relates to a process for modifying the surface of hard engineering ceramic materials. These materials include compounds (oxides, carbides, nitrides, borides) of the elements silicon, boron and other transition metals, and for the purposes of the present invention can be generally defined as having a room temperature Knoop indentation hardness, using a 1kg normal load, greater than 1000kg/mm² (or 10GPa).

Hard engineering ceramic materials are relatively new and in many cases the full extent of their useful applications is yet to be fully explored. However, it is known that such materials have a tendency to fracture, rather than to deform plastically, when subjected to stress at temperatures below about 0.5 of their melting points ($0.5 T_m$) - that is to say, they tend to be brittle at such temperatures. Consequently they are difficult to shape and, most often, components made from such materials must be made by hot pressing or sintering processes followed by grinding to the final dimensions. Grinding inevitably introduces micro surface defects and cracks which can contribute to premature failure whilst in service, particularly in tribological applications such as a piston within a piston cylinder. These difficulties in working such materials obviously limit their useful applications.

It is an object of the present invention to provide a process for modifying the surface of hard engineering ceramic materials and, more specifically, a process whereby micro surface defects and cracks in the surface

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of the material can be annealed.

According to a first aspect of the present invention there is provided a process for modifying the surface of hard engineering ceramics materials wherein the surface of the material is subjected to plastic deformation caused by point/line loading transmitted by the surface of a second material.

Throughout this specification the term "point loading" is intended to define forces transmitted from a pointed surface to a plane surface as between a pencil and paper. The term "line loading" is intended to define the forces transmitted from a line surface to a plane surface as between a wedge, chisel or cylinder and a plane surface.

Preferably, the second material is loaded against the hard engineering ceramics material which is being treated at a sufficiently high temperature to cause the second material to flow into and replicate the surface features of the hard engineering ceramics material by creep. Conveniently, this process is carried out at a temperature less than $0.5 T_m$. (T_m equals the temperature at which the hard engineering ceramics material melts). The second material may conveniently comprise a second hard engineering ceramic material, but this may be of the same hardness or even softer than the hard engineering ceramic material which is being treated.

Using the process of the present invention two major benefits accrue:-

1. Firstly, defects introduced by grinding the material, such as cracks, are healed with a consequent improvement in wear resistance.

2. Secondly, small changes in surface topography

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can be developed and controlled. Thus, one ceramic surface can be caused to develop optimum conformity to another by deforming these surfaces under creep conditions. This means that a piston and piston cylinder can be treated to conform with each other for optimum tribological coupling in use at normal operating temperatures.

Conveniently, the surface of the hard engineering ceramics material can be hardened by repeatedly traversing (rubbing) it with a softer lubricated metal. It has been shown by experiment that the hardness of the hard engineering ceramics material may be increased by some 60% in this way and the increase in hardness is permanent. Furthermore, the wear resistance of the material is increased under three-body-wear conditions that is to say where wear debris or oxide particles are trapped between two surfaces which are wearing against one another.

It has been found that the principle variables which have to be controlled during treatment of a hard engineering ceramics material in accordance with the process of the present invention to achieve the benefits ascribed above are as follows:-

1. The stress developed during point/line loading must be sufficient to exceed the critical resolved shear stress to move and multiply dislocations, in the crystalline solid being modified, but not to develop localised cracking.

2. The temperature at which the process is carried out must be less than that at which adhesion and seizure would occur between the surface of the hard engineering ceramics material being treated and the second material applying the point/line loading through processes of

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bulk transfusion, yet high enough to enable significant dislocation mobility. This will usually be in the range 0.3 T_m to 0.5 T_m .

3. The optimum time of contact between the surfaces of the hard engineering ceramics material and the second material applying the point/line loading will be dependent upon temperature.

4. The atmosphere in which the process of the present invention is carried out may be controlled, e.g. it may be vacuum, inert, or reactive, in order to prevent degradation of the surface or to induce improved surface properties (such as adjustments to non-stoichiometric composition, etc.).

According to a second aspect of the present invention there is provided a process for treating the surface of a component comprised of hard engineering ceramics materials wherein the surface of the material is subjected to plastic deformation caused by point/line loading transmitted by the surface of a second hard engineering ceramic material.

In a preferred embodiment of the present invention two components both comprised of hard engineering ceramics materials and intended for use in a tribological application are treated in accordance with the process of the present invention, one against the other, to ensure optimum conformity between facing surfaces of the two components. The components may both be comprised of the same hard engineering ceramics material, or one may be comprised of a softer hard engineering ceramics material than the other.

An embodiment of the present invention will now be described, by way of example.

Consider a piston within a piston cylinder. Either

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or both of these may be fabricated using a hard engineering ceramics material to attain the benefits and advantages inherent in using such materials. However, using conventional fabrication techniques the hard engineering ceramics material must be ground to its final dimensions if the piston is to fit accurately within the bore of the piston cylinder and to a greater or lesser extent this gives rise to micro surface defects and cracks in the ground surface.

In the process of the present invention the piston and the piston cylinder are fabricated conventionally up to the stage immediately prior to grinding except that the bore of the piston cylinder is somewhat undersized and the diameter of the piston ring corresponds to the ultimate or specified diameter of the piston cylinder bore. Conventionally, the piston ring is fabricated from a harder engineering ceramics material than that of the piston cylinder itself, although it should be understood that they may equally be of the same hardness.

The piston ring is introduced into the bore of the piston cylinder at a temperature roughly equal to $0.5 T_m$ and is then driven the working length of the piston cylinder bore. The perimeter of the piston ring contacting the internal surface of the piston cylinder bore defines a line contact there between and the line loading between the two surfaces ensures that the surface of the piston ring contacting the internal surface of the piston cylinder is modified by the process of creep to conform to the internal surface of the piston cylinder. The actual rate of travel of the piston ring through the piston cylinder bore is determined and specified in accordance with the other

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operating characteristics of the process, such as roughness of the surface to be modified, the degree of undersize, the temperature and the rate of deformation.

Modification of the piston ring to match the internal surface of the piston cylinder bore would follow the same process as that described previously, but in this instance the diameter of the piston ring is slightly oversize and the piston cylinder is fabricated from the harder engineering ceramics material.

It should be appreciated that whilst the present invention has been described with reference to a piston and piston cylinder other components made from hard engineering ceramics may be treated using the process of the present invention. It will be readily apparent to a person skilled in the art that the equipment or apparatus used to implement the process of the present invention will vary from one component to another according to its particular shape and contour, but that the basic principle of applying a point/line load over its entire surface remains the same.

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CLAIMS

1. A process for modifying the surface of a hard engineering ceramic material, wherein a point or line load is applied to the surface of the hard engineering ceramic material by a second material such as to cause plastic deformation of the hard engineering ceramic material.

2. A process according to claim 1, wherein the said second material is repeatedly traversed across the surface of the hard engineering ceramic material.

3. A process according to claim 1 or 2, wherein the hard engineering ceramic material is treated as a sufficiently high temperature to ensure that the second material flows into and replicates the surface features of the hard engineering ceramic material by "creep".

4. A process according to claim 3, wherein the process is carried out at a temperature in the range of $0.3T_m$ to $0.5T_m$, where T_m equals the temperature at which the hard engineering ceramic material melts.

5. A process according to any preceding claim, wherein the second material comprises a hard engineering ceramic material, the hardness of which is not greater than that of the hard engineering ceramic material to be treated.

6. A process according to any one of claims 1 to 4, wherein the second material comprises a relatively soft lubricated metal.

7. A process according to any preceding claim, wherein a first engineering component is fabricated from the hard engineering ceramic material and a second engineering component is fabricated from the second material, which first and second components are used in a tribological application and between them define a point or line contact such that in use the second engineering component modifies the surface of the first engineering component.

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8. A process according to claim 7, wherein the first engineering component comprises a piston ring and the second engineering component comprises a piston cylinder, or vise-versa.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 88/00950

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) * According to International Patent Classification (IPC) or to both National Classification and IPC IPC4: B 28 B 11/00, C 04 B 37/02, 41/88, C 23 C 17/00														
II. FIELDS SEARCHED <div style="text-align: center; margin-top: 10px;">Minimum Documentation Searched ⁷</div> <table style="width: 100%; border: none;"> <tr> <td style="width: 25%; border: none;">Classification System</td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: none; padding: 10px;">IPC4</td> <td style="border: none; padding: 10px;">B 22 D; B 23 P; B 28 B; B 32 B; C 04 B; C 23 C</td> </tr> </table> <div style="text-align: center; margin-top: 10px;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸</div>			Classification System	Classification Symbols	IPC4	B 22 D; B 23 P; B 28 B; B 32 B; C 04 B; C 23 C								
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III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹ <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category ⁹</th> <th style="width: 70%;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%;">Relevant to Claim No. ¹³</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>DE, A1, 2831207 (GOETZE AG) 24 January 1980, see page 1 - page 2; claims 1-7 --</td> <td style="text-align: center; vertical-align: top;">1-8</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>DE, A1, 3600677 (RHEINHÜTTE VORM LUDWIG BECK GMBH & CO) 16 July 1987, see column 1, line 36 - line 41 --</td> <td style="text-align: center; vertical-align: top;">1-8</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>GB, A, 2148270 (THE BRITISH CERAMIC RESEARCH ASSOCIATION LIMITED) 30 March 1985, see page 1, line 93 - line 104 -- -----</td> <td style="text-align: center; vertical-align: top;">1-8</td> </tr> </tbody> </table>			Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	A	DE, A1, 2831207 (GOETZE AG) 24 January 1980, see page 1 - page 2; claims 1-7 --	1-8	A	DE, A1, 3600677 (RHEINHÜTTE VORM LUDWIG BECK GMBH & CO) 16 July 1987, see column 1, line 36 - line 41 --	1-8	A	GB, A, 2148270 (THE BRITISH CERAMIC RESEARCH ASSOCIATION LIMITED) 30 March 1985, see page 1, line 93 - line 104 -- -----	1-8
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<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p>* Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 48%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"Δ" document member of the same patent family</p> </div> </div>														
IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; padding: 5px;"> Date of the Actual Completion of the International Search 22nd December 1988 </td> <td style="width: 50%; border: none; padding: 5px;"> Date of Mailing of this International Search Report <div style="text-align: right; font-weight: bold; font-size: 1.2em;">20 JAN 1989</div> </td> </tr> <tr> <td style="border: none; padding: 5px;"> International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div> </td> <td style="border: none; padding: 5px;"> Signature of Authorized Officer <div style="text-align: right;"> P.C.G. VAN DER PUTTEN </div> </td> </tr> </table>			Date of the Actual Completion of the International Search 22nd December 1988	Date of Mailing of this International Search Report <div style="text-align: right; font-weight: bold; font-size: 1.2em;">20 JAN 1989</div>	International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: right;"> P.C.G. VAN DER PUTTEN </div>								
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A1- 2831207	24/01/80	NONE	
DE-A1- 3600677	16/07/87	EP-A- 0237704	23/09/87
GB-A- 2148270	30/05/85	NONE	